Transition Metal Basics

Question Paper

Level	International A Level
Subject	Chemistry
Exam Board	Edexcel
Topic	Transition Metals & Organic Nitrogen Chemistry
Sub Topic	Transition Metal Basics
Booklet	Question Paper

Time Allowed: **86 minutes**

Score: **/71**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 Which of the following elements is both a d-block element and a transition element?

- ☒ **A** Calcium
- ☒ **B** Copper
- ☒ **C** Scandium
- ☒ **D** Zinc

(Total for Question 1 = 1 mark)

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2 These are four successive ionization energies (in kJ mol^{-1}) of four different elements.
Which could be those of a transition element?

- ☒ **A** 658 1310 9573
- ☒ **B** 578 18
- ☒ **C** 738 14
- ☒ **D** 496 45

(Total for Question 2 = 1 mark)

3 The electronic configuration of the element vanadium is

		3d					4s
☒ **A**	[Ar]	↑↓	↑↓	↑			
☒ **B**	[Ar]	↑	↑				
☒ **C**	[Ar]	↑	↑				↑
☒ **D**	[Ar]	↑	↑				↑↓

(Total for Question 3 = 1 mark)

4 Transition metals typically form a number of ions which are stable in aqueous solution. The **best** explanation for this property is that

☒ **A** the differences in the successive ionization energies are similar to the differences in hydration enthalpies of the ions.

☒ **B** all the ions are formed by the removal of electrons from the d subshell.

☒ **C** the ionization energies of transition metals are low.

☒ **D** the hydration enthalpies of transition metal ions are always more exothermic than those of ions of s and p block metals.

(Total for Question 4 = 1 mark)

5 The electronic configuration of the iron(II) ion, Fe^{2+}, is

		3d					4s
☒ **A**	[Ar]	↑↓	↑	↑			↑↓
☒ **B**	[Ar]	↑	↑				↑↓
☒ **C**	[Ar]	↑	↑				↑
☒ **D**	[Ar]	↑↓	↑	↑			

(Total for Question 5 = 1 mark)

6 Transition metal compounds often have catalytic properties. The **best** explanation for this is that

☒ **A** transition metal compounds usually have a much larger surface area than other metal compounds.

☒ **B** transition metal ions readily promote electrons to higher energy levels by absorbing electromagnetic radiation in the visible region.

☒ **C** relatively small amounts of energy are required to change the oxidation state of a transition metal.

☒ **D** the ionization energies of transition metals are much lower than those of other metals.

(Total for Question 6 = 1 mark)

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7 What are the shapes of the dichlorocuprate(I) ion, $CuCl_2^-$, and the tetrachlorochromate(III) ion, $CrCl_4^-$?

	$CuCl_2^-$	$CrCl_4^-$
☒ **A**	V shaped	tetrahedral
☒ **B**	linear	tetrahedral
☒ **C**	V shaped	square planar
☒ **D**	linear	square planar

(Total for Question 7 = 1 mark)

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8 The iron(II) ion forms complexes with monodentate ethanoate ions and bidentate ethanedioate ions. The complexes with ethanedioate ions are more stable. What is the best explanation for this?

☒ **A** Ethanedioate ions form stronger bonds than ethanoate ions with iron(II) ions.

☒ **B** Ethanedioic acid is a stronger acid than ethanoic acid.

☒ **C** The formation of the ethanedioate complex produces more particles in solution.

☒ **D** Ethanedioic acid forms stronger hydrogen bonds than ethanoic acid.

(Total for Question 8 = 1 mark)

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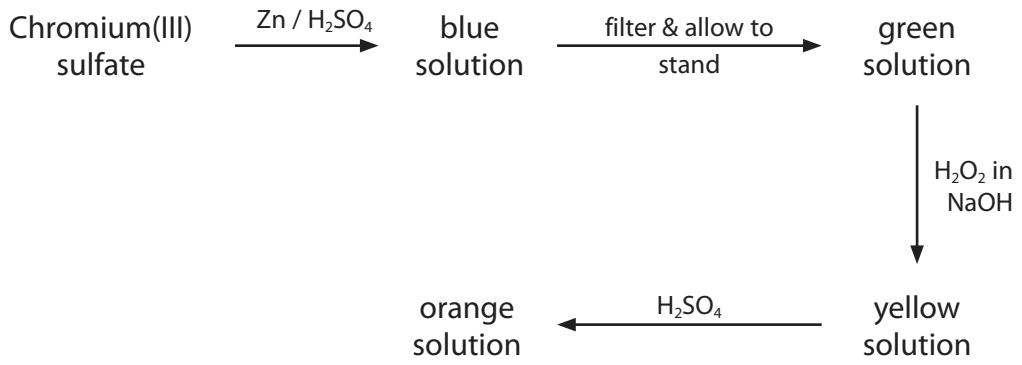
9 The diagram below summarises a sequence of reactions involving chromium compounds.



How many different oxidation states of chromium are involved in this sequence?

- ☒ **A** 2
- ☒ **B** 3
- ☒ **C** 4
- ☒ **D** 5

(Total for Question 9 = 1 mark)

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10 The electronic configuration of the element chromium is

			3d				4s
☒ **A**	[Ar]	↑	↑				↑↓
☒ **B**	[Ar]	↑	↑				↑
☒ **C**	[Ar]	↑↓	↑↓				↑↓
☒ **D**	[Ar]	↑↓	↑↓	↑			↑

(Total for Question 10 = 1 mark)

11 In which of the following compounds does iron have the highest oxidation number?

☒ **A** Fe_3O_4

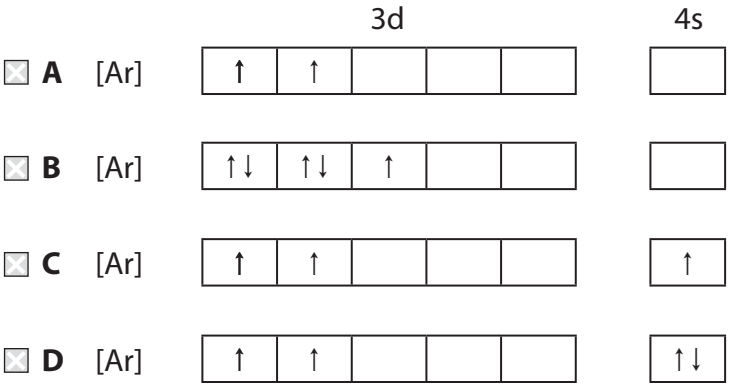
☒ **B** K_2FeO_4

☒ **C** $Na_4Fe(CN)_6$

☒ **D** $Na_3Fe(CN)_6$

(Total for Question 11 = 1 mark)

12 What is the electronic configuration of the Fe^{3+} ion?



(Total for Question 12 = 1 mark)

13 Ammonia gas is formed in the combustion of biomass fuels and is a significant pollutant when it is released directly into the atmosphere. One method of removing this ammonia involves its oxidation using a titanium(IV) oxide catalyst.

The **best** explanation for the use of titanium(IV) oxide is that the titanium

☒ **A** contains many active sites on which the reaction can occur.

☒ **B** is readily oxidized to a higher oxidation state which can then be reduced back to oxidation state +4.

☒ **C** is readily reduced to a lower oxidation state which can then be oxidized back to oxidation state +4.

☒ **D** has partially filled d orbitals in its +4 oxidation state.

(Total for Question 13 = 1 mark)

14 A transition metal ion, M, forms a complex with a bidentate ligand, B. The formula of the complex is MB_3 so the shape of the complex is most likely to be

☒ **A** trigonal planar.

☒ **B** pyramidal.

☒ **C** trigonal bipyramidal.

☒ **D** octahedral.

(Total for Question 14 = 1 mark)

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15 Which of the following lists **all** the types of bond that are present in a crystalline sample of the compound tetraamminecopper(II) sulfate?

☒ **A** Ionic, covalent and dative covalent

☒ **B** Ionic and dative covalent

☒ **C** Ionic and covalent

☒ **D** Covalent and dative covalent

(Total for Question 15 = 1 mark)

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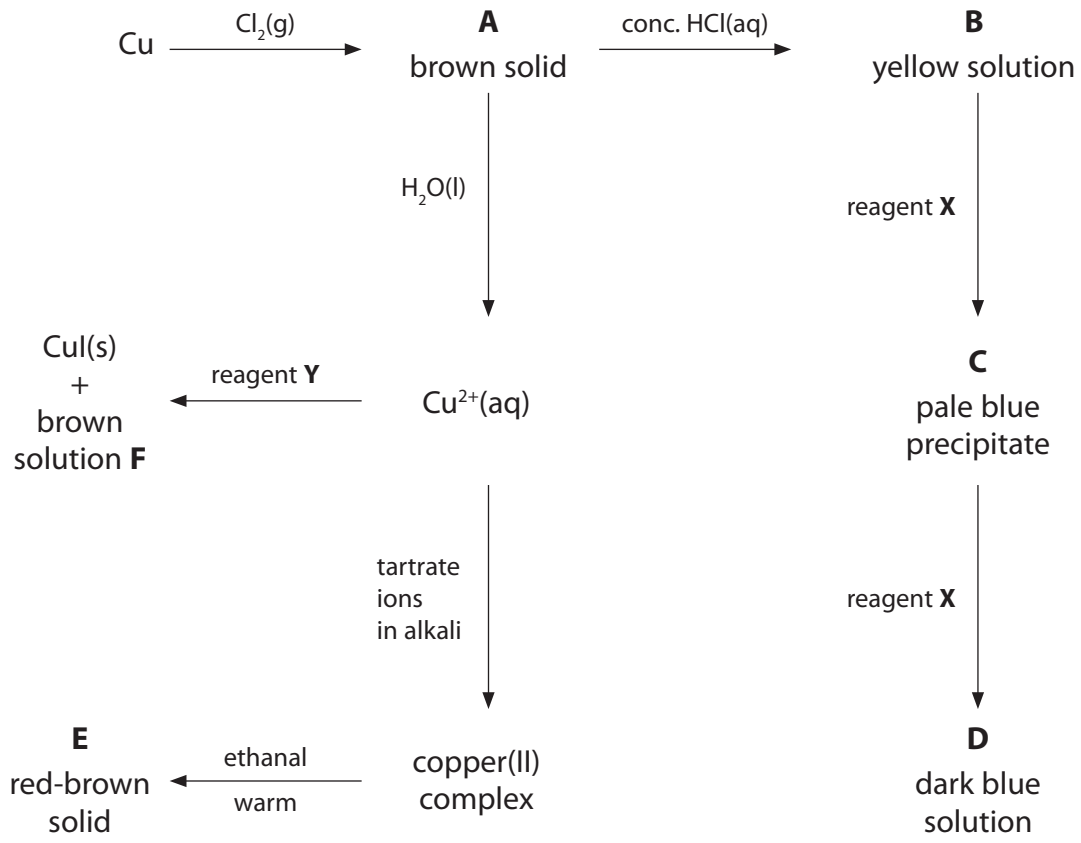
16 The scheme below summarises some reactions of copper and its compounds.



(a) (i) Identify the copper containing species **A** to **E** either by name, including the oxidation number, or by formula. Also, identify the brown solution, **F**.

(6)

A .....

B .....

C .....

D .....

E .....

F .....

(ii) Identify the reagents **X** and **Y**.

(2)

X .....

Y .....

(iii) Identify the **organic** product of the reaction between the copper(II) complex and ethanal. Hence explain the role of ethanal in the reaction.

(2)

(iv) The reaction between $Cu^{2+}(aq)$ and reagent **Y** forms CuI(s) and a brown solution, **F**. This reaction is the first stage in a method for the determination of the concentration of $Cu^{2+}(aq)$.

Outline briefly how this method is used. Practical details are **not** required.

(1)

*(b) (i) Explain why **B** is coloured.

(4)

(ii) Explain why **B** and **D** have different colours.

(2)

(c) Aqueous copper(I) ions undergo a disproportionation reaction.

(i) Write the ionic equation for this reaction. Include state symbols in your answer.

(1)

(ii) Explain, stating the relevant oxidation numbers, why the reaction in (c)(i) is classified as a disproportionation.

(1)

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(iii) se the standard reduction potentials on page 17 of the Data Booklet to calculate $E^{\ominus}_{cell}$ for this disproportionation. Hence show that this reaction is thermodynamically feasible.

(2)

(Total for Question 16 = 21 marks)

17 This question is about the element chromium and some of its compounds.

(a) (i) Complete the electronic configuration of the chromium atom, using the s, p, d notation.

(1)

[Ar] .....

*(ii) State how this electronic configuration of the chromium atom is unusual compared with most other transition metals.

Give **two** reasons why chromium has this electronic configuration.

(2)

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(b) (i) A solution containing chromium(II) ions can be produced in the laboratory by reducing a solution of potassium dichromate(VI) using zinc in 50% hydrochloric acid. This reaction takes place in two steps. Dichromate(VI) ions are reduced to chromium(III) ions and the chromium(III) ions are then reduced to chromium(II) ions.

Use the relevant standard reduction potentials from page 17 or standard electrode potentials on pages 14 and 16 of the Data Booklet to calculate $E^{\ominus}_{cell}$ for each step.

Use your $E^{\ominus}_{cell}$ values to explain why both steps are spontaneous.

(3)

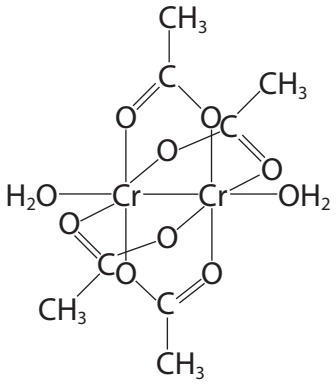
(ii) State the colour changes you would expect to see during this reaction.

(1)

(iii) A student suggests that the hydrogen produced by the reaction of the zinc with hydrochloric acid in this experiment is a serious risk. Evaluate the student's suggestion.

(1)

(c) Chromium(II) ions in aqueous solution are quickly oxidized by the oxygen in air. One method of stabilising chromium(II) ions is by adding a solution of sodium ethanoate, forming a complex, $[Cr_2(CH_3CO_2)_4(H_2O)_2]$. This complex may be represented by the structure below.



(i) What type of ligand is the ethanoate ion in this complex?

(1)

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(ii) State the type of bonding which occurs between the ligands and the chromium(II) ions.

(1)

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(iii) Suggest **two** unusual features in the structure and bonding of this complex.

(2)

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(iv) This complex is red.
Explain why the colour of chromium(II) ethanoate is different from that of $Cr(H_2O)_6^{2+}(aq)$.

(2)

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(v) Predict the number and relative areas of the peaks in the **low** resolution proton nmr spectrum of $Cr_2(CH_3CO_2)_4(H_2O)_2$.

Justify your answers.

(2)

(d) An experiment is carried out to check the oxidation number of chromium in chromium(II) ethanoate $Cr_2(CH_3CO_2)_4(H_2O)_2$.

1.00 g (2.66×10^{-3} mol) of chromium(II) ethanoate is dissolved in 25 cm^3 of 1.00 mol dm^{-3} sulfuric acid.

The solution is diluted with distilled water until the volume is 250 cm^3.

25.0 cm^3 portions of the diluted solution are titrated with 0.00750 mol dm^{-3} potassium manganate(VII).

Calculate the volume of potassium manganate(VII) needed to oxidize the chromium(II) ions present in each 25.0 cm^3 portion to the +6 oxidation state. The manganese is reduced to the +2 oxidation state.

Comment on your answer and suggest how the experiment could be improved to give a more suitable titre.

(5)

Comment .....

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(Total for Question 17 = 21 marks)

18 Crystals of copper(II) sulfate dissolve in water to form a blue solution, **A**. When dilute aqueous ammonia is added to this solution, a pale blue precipitate, **B**, forms which dissolves in excess aqueous ammonia to form a dark blue solution, **C**.

(a) (i) Give the **formula** of the copper species in **A**, **B** and **C**. You should include all of the ligands present in each species.

(3)

A .....

B .....

C .....

(ii) Explain why solution **A** is coloured.

(4)

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(iii) Explain why solution **A** is a different colour to solution **C**.

(2)

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(b) A more concentrated solution of **C** may be prepared by using concentrated aqueous ammonia in place of dilute aqueous ammonia. The crystalline sulfate of **C** may be obtained by cooling the mixture in an ice bath and adding ethanol. The filtered crystals may be recrystallized using ethanol as the solvent.

The steps of the recrystallization are summarised below. In the spaces provided, explain the purpose of each step, referring particularly to any words in **bold** type.

(5)

Step 1 The solid was dissolved in the **minimum** amount of hot ethanol.

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Step 2 The **hot** solution was **filtered**.

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Step 3 The filtrate was cooled in an **ice bath**.

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Step 4 The mixture was **filtered** using **suction filtration**.

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(Total for Question 18 = 14 marks)